Equilibrium 8 dec file 2

H.W

Q. $Fe_2O_3(s)$ may be converted to Fe by the Rx^n :-

$Fe_2O_3(s) + 3H_2(g) \rightleftharpoons 2Fe(s) + 3H_2O(g)$

$K_c = 8$ at $\boxed{\text{Temp } 720^\circ C}$.

What percentage of H_2 remains unreacted after the Rx^n has come to equilibrium?

a) ≈22% b) ≈34% c) ≈66% d) ≈78%

Ionic Eq^m ⇒ Only possible in Case of Weak Electrolyte. (W.E)

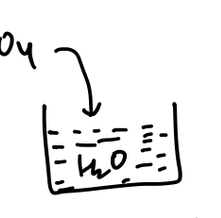
⊛ Lechatlier's principle only works for W.E.

Electrolyte → that substance which dissociate into ions in aqueous medium.

Strong Electrolyte ⇓ $\boxed{\text{Dissociate 100\% into ions}}$ → α=1

Weak Electrolyte ⇓ Does not dissociate 100% into ions. → α<1

eg. H_2SO_4



$1H_2SO_4 \longrightarrow 2H^+ + 1SO_4^{2-}$

2 mole 0 0

2−2=0 4 mole 2 mole

$\boxed{\text{Degree of ionization of strong Electrolyte} = 1 = \alpha}$

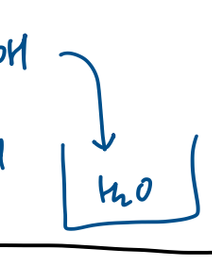
eg. Strong Acid (S.A), Strong Base (S.B), All Salts.

S.A → $\boxed{HClO_4, HI, HBr, H_2SO_4, HCl, HNO_3}$

S.B → Hydroxides of Group 1 and Group 2 (except LiOH, $Be(OH)_2$, $Mg(OH)_2$)

Salt → CH_3COONa, NH_4Cl, K_2SO_4 etc.

eg. CH_3COOH Weak Acid



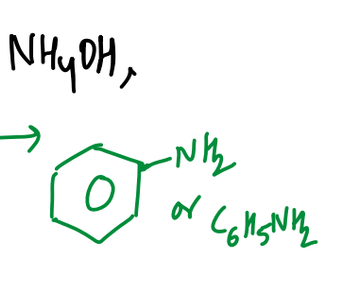
$\boxed{CH_3COOH \rightleftharpoons H^+ + CH_3COO^-}$

$\boxed{\alpha < 1}$ → Degree of ionization.

eg. Weak Acids (W.A), Weak Bases (W.B)

W.A → CH_3COOH, HNO_2, HF, H_2CO_3, H_3PO_4 etc.

W.B → $NH_3(aq)$ or NH_4OH, Aniline, $Mg(OH)_2$ etc.



Acid Base Theories

① **Arrehenius Concept** :-

Acid :- H^+ donor in aq medium. → which ↑es $[H^+]$ in Sol^n. $[H^+] > [OH^-]$

eg:- HCl, H_2SO_4 etc.

Neutral: $\boxed{H_2O}$ ⇒ very weak electrolyte, $[H^+] = [OH^-]$

BASE :- $\bar{O}H$ donor in aq medium. → ↑es $[OH^-]$ in Sol^n such that $\boxed{[OH^-]_{Total} > [H^+]_{Total}}$

eg. NaOH, KOH, $Ca(OH)_2$ etc.

② **Bronsted-Lowry Concept**

Acid :- Species (Molecule or ion) that donate H^+ to another species.

Base :- Species (molecule or ion) that accepts a proton (H^+) from another species.

eg. $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$

HCl: B.Acid, H^+ donor; H_2O: B.BASE, H^+ acceptor; H_3O^+: C.A; Cl^-: C.B

$HCl \xrightarrow{-1H^+} Cl^-$ — HCl Acid; Cl^- (C.B) Conjugate Base of HCl

$H_2O \xrightarrow{+1H^+} H_3O^+$ — H_2O Base; H_3O^+ (C.A) Conjugate Acid of H_2O

$H_2SO_4 \longrightarrow \boxed{HSO_4^-} + H^+$ — C.B of H_2SO_4

$\bar{O}H \longrightarrow O^{2-} + H^+$ — C.B of $\bar{O}H$

$Cl^- \xrightarrow{+H^+} HCl$ — C.A of Cl^-

$H_2O \xrightarrow{+H^+} (H_3O)^+$ — C.A

⊛⊛ To write Conjugate Acid or Base only 1 H^+ loss & gain is considered.

$HNO_3 + H_2SO_4 \rightleftharpoons (HSO_4)^- + (H_2NO_3)^{\oplus}$

HNO_3: B.BASE; H_2SO_4: B.Acid; $(HSO_4)^-$: C.B of H_2SO_4; $(H_2NO_3)^{\oplus}$: C.A of HNO_3

Strength: $HClO_4 > HI > HBr > H_2SO_4 > HCl > HNO_3$

$H_2SO_4 + HCl \rightleftharpoons H_2Cl^+ + HSO_4^{\ominus}$

H_2SO_4: Acid Bronsted; HCl: BASE Bronsted; H_2Cl^+: C.A of HCl; $HSO_4^{\ominus}$: C.B of H_2SO_4

Q. Write C.B of following?

1) $H_2O \xrightarrow{-H^+} \bar{O}H$
2) $\bar{O}H \xrightarrow{-H^+} O^{2-}$
3) $HNO_3 \xrightarrow{-H^+} NO_3^{\ominus}$
4) $H_2CO_3 \xrightarrow{-H^+} HCO_3^-$
5) $[Fe(H_2O)_6]^{3+} \xrightarrow{-1H^+} [Fe(H_2O)_5(OH)]^{+2}$

- C.A of HNO_3 is $(H_2NO_3)^+$
- species which can donate as well accept H^+ are called Amphiprotic species.

eg H_2O, NH_3, NH_2^- etc.

---

③ **Lewis Acids and Bases** :-

Lewis Acid :- $\boxed{e^- \text{ deficient species}}$ → have vacant orbital

examples of Lewis Acid :- ① +ve species

eg. H^+, Ag^+, Fe^{2+}, Cu^+ etc.

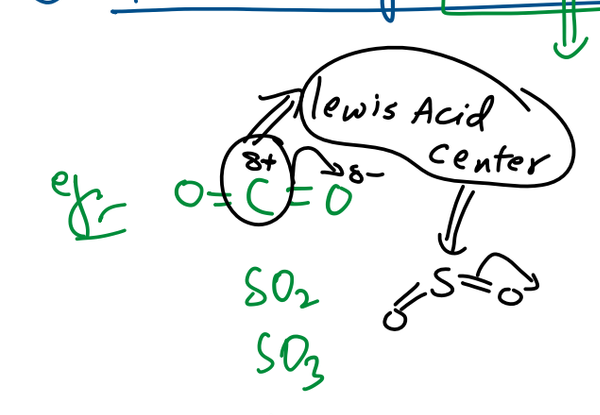
② Neutral species Having vacant p or d orbital in their Valence shell :-

eg. $AlCl_3$, BCl_3, BF_3, BI_3, BBr_3, $BeCl_2$ } vacant p

SiX_4, GeX_4, PX_3, PF_5, SbF_5, SF_4, $FeCl_3$ etc. → vacant d

③ Species Having $\boxed{\text{Hetero double / triple Bond}}$:- ⇓ Between 2 Different atom.

eg.



SO_2, SO_3, Aldehyde, Ketone, R-CN etc.

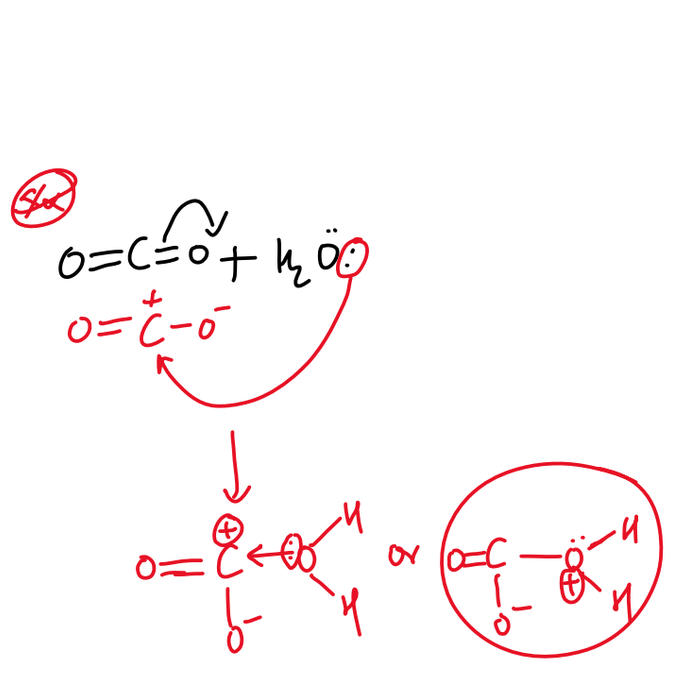
Lewis BASE :- e^- rich species ; e^- donor species

eg. i) Neutral species Having lone pair

$H_2\ddot{O}:$, $\ddot{N}H_3$, $:PH_3$, $R-\ddot{N}H_2$, $R-\ddot{O}H$ etc.

(ii) -ve species :-

Cl^-, $CN^{\ominus}$, $\bar{O}H$, X^-, $\bar{N}H_2$ etc.



$\boxed{H_2O}$

Self ionization of H_2O (Autoprotolysis of H_2O)

$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + \overset{\ominus}{O}H(aq)$

B.acid, B.BASE, C.A, C.B

$\boxed{2H_2O(l) \rightleftharpoons H_3O^+(aq) + \bar{O}H(aq)}$

or

$\boxed{H_2O(l) \rightleftharpoons H^+(aq) + \bar{O}H(aq)}$ ⇒ ΔH = +ve (Endo)

$[H^+(aq)] = [H_3O^+] = [H_5O_2]^+ = [H_7O_3]^+ \dots$

$[H^+(H_2O)]$, $[H^+(H_2O)_2]$, $[H^+(H_2O)_3]$

$[OH(aq)]^{\ominus} = [H_3O_2]^- = [H_5O_3]^- = ---$

$\boxed{1\,L\,H_2O}$

$d_{H_2O} \approx 1 g/ml$ or $1 g/cc$ or $1 g/cm^3$ ≈ $1000 kg/m^3$

$1\,L\,H_2O \Rightarrow 1000\,ml\,H_2O \Rightarrow 1000\,g\,H_2O$ $(d_{H_2O} = 1)$

moles of H_2O = $\frac{1000}{18}$ = $\boxed{55.5 \text{ moles per Litre of } H_2O}$

$\boxed{[H_2O] = 55.5\,M}$ = C Molar

$1H_2O(l) \rightleftharpoons H^+(aq) + \bar{O}H(aq)$

t=0: C Moles/Litre, 0, 0

at eq^m: $C(1-\alpha)$ = $C - C\alpha$, $C\alpha$, $C\alpha$

let $\boxed{\alpha}$ is degree of ionization of H_2O → part of 1 mole ionized.

1 → α
2 → 2α
C → Cα

$K_{eq} = \frac{[H^+][OH^-]}{[H_2O]}$

$\boxed{K_{eq}[H_2O]} = \boxed{K_w} = [H^+][OH^-] = (C\alpha)(C\alpha) = (C\alpha)^2$

Const; K_w → Keq for H_2O; Ionic Product of H_2O at Saturation point

$\boxed{K_w \rightarrow \text{only temp. dependent}}$ ✓ ΔH = +ve $\boxed{K_w \propto T}$ $\boxed{T\uparrow, K_w\uparrow}$

It was found that at 25°C (298K), $\boxed{K_w = 1 \times 10^{-14}}$

$K_w = 10^{-14} = [H^+][OH^-]$

Since $\boxed{[H^+] = [OH^-]}$

$10^{-14} = [H^+]^2$

✓ $\boxed{[H^+] = 10^{-7} M}$ → out of 55.5 moles of H_2O, only 10^{-7} moles of H^+ are obtained per Litres; which suggest that ionization of H_2O is very poor. and H_2O is very weak electrolyte.

$C\alpha = [H^+] = [OH^-] = 10^{-7}$

$\alpha = \frac{10^{-7}}{C} = \frac{10^{-7}}{55.5} = \boxed{1.8 \times 10^{-9}}$

% ionization of H_2O at eq^m at 25°C = $100 \times \alpha$ = $\boxed{1.8 \times 10^{-7}\,\%}$ → very very small ionization.

$K_w = [H^+][OH^-] = (C\alpha)(C\alpha)$

$(C\alpha)^2 = K_w$ or $[H^+]^2 = K_w$

$[H^+] = \sqrt{K_w}$

25°C: $\boxed{K_w = 10^{-14}}$

$[OH^-] = [H^+] = 10^{-7}\,M$

$C\alpha = 10^{-7}$ → $\boxed{.0000001 \text{ Moles}}$

$\alpha = \frac{10^{-7}}{55.5} = \boxed{1.8 \times 10^{-9}}$

% ionizat^n = $\boxed{1.8 \times 10^{-7}\,\%}$

$\boxed{K_{eq} \propto T}$ ΔH > 0

$\boxed{K_{eq} \propto \frac{1}{T}}$ ΔH < 0

$\boxed{K_w \propto T}$ $\Delta H_{ionizat^n}(H_2O)$ = +ve

$T\uparrow\ K_w\uparrow$

0°C $K_w \approx 10^{-16}$ → $pK_w = 16$, pH = 8 = pOH

100°C $K_w \approx 10^{-12}$ → $pK_w = 12$, pH = 6 = pOH

$\boxed{pH = -\log[H^+] = -\log 10^{-7} = 7 \\ pOH = -\log[OH^-] = -\log 10^{-7} = 7}$ → at 25°C $K_w = 10^{-14}$

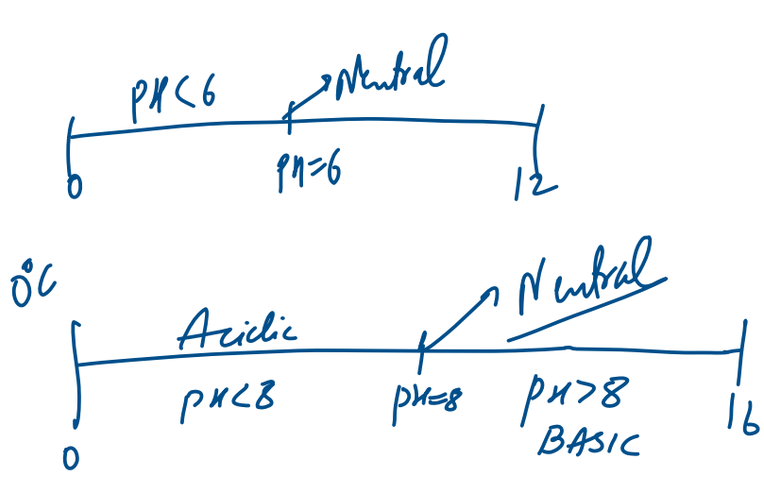
$K_w = [H^+][OH^-]$

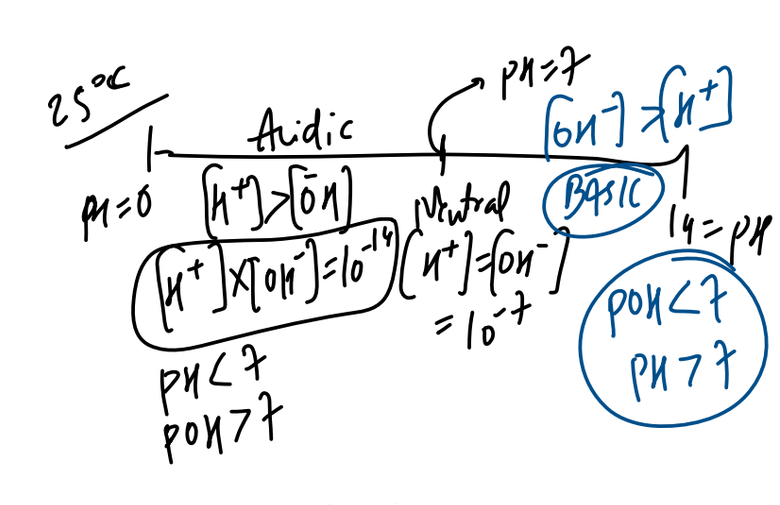
$-\log K_w = -\log[H^+] - \log[OH^-]$

$\boxed{pK_w = pH + pOH}$

25°C: 14, 7, 7

$\boxed{pH + pOH = pK_w}$





$pH = -\log[H^+] = \log\frac{1}{[H^+]}$

$\boxed{pH}$ Scale ⇒ defined by Sorenson → potenz of Hydronium ion

pH of Sol^n ⇒ negative logarithm of Hydronium ion Concentration.

$pH = -\log[H_3O^+] = -\log[H^+] = \log\frac{1}{[H^+]}$

$\boxed{[H^+] = 10^{-pH}}$ $\boxed{[H^+]\uparrow es, \text{ pH of } Sol^n \downarrow es}$

$-\log[H^+] = pH$, $[H^+] = 10^{-pH}$

if $pH = 3$: $[H^+] = 10^{-3}$, $[H^+][OH^-] = 10^{-14}$, $[OH^-] = \frac{10^{-14}}{10^{-3}} = 10^{-11}$, $\boxed{pOH = 11}$

Similarly, $pOH = -\log[OH^-]$

$\boxed{[OH^-] = 10^{-pOH}}$

$\boxed{pK_w = -\log(K_w)}$ ⇒ at 25°C, $K_w = 10^{-14}$

$pK_w = -\log(10^{-14}) = \boxed{14}$

$K_w = [H^+][OH^-]$

$-\log K_w = -\log[H^+] - \log[OH^-]$

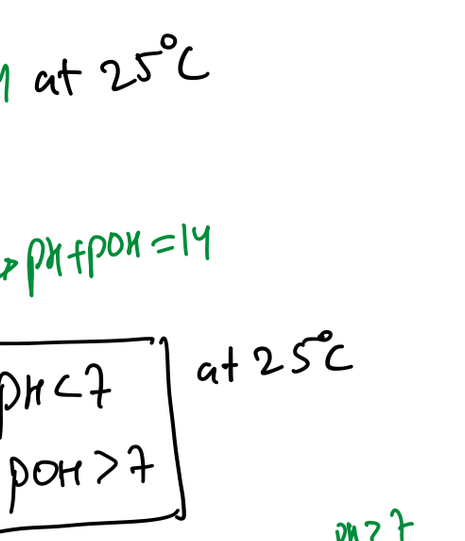
$\boxed{14 = pH + pOH}$ at 25°C

neutral H_2O ⇒ $[H^+] = [OH^-] = 10^{-7} M$ at 25°C

$\boxed{pH = 7 = pOH}$

Acidic Sol^n :- $[H^+] > [OH^-]$, $\boxed{pH < pOH}$ → pH+pOH=14; $\boxed{pH<7 \\ pOH>7}$ at 25°C

BASIC Sol^n :- $[OH^-] > [H^+]$, $\boxed{pH>7 \\ pOH<7}$ at 25°C → pH+pOH=14



⊛⊛ Effect of Temp on pH of H_2O :- $\boxed{\Delta H + H_2O \rightleftharpoons H^+ + OH^-}$ → Endo

$\boxed{\text{Ionization of } H_2O\ \uparrow es \text{ with } \uparrow e \text{ in Temp.}}$ → Endothermic process

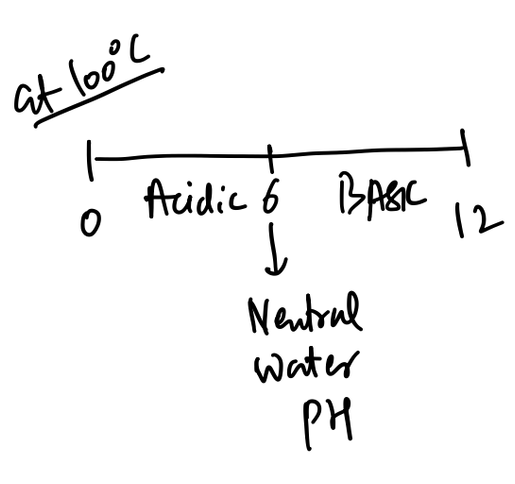
$\boxed{K_{eq} \propto T}$ $\boxed{K_w \propto T}$ T↑es, K_w↑es

at 100°C, $K_w \approx 10^{-12}$

$[H^+][OH^-] \approx 10^{-12}$

pH + pOH = 12

$[H^+] = [OH^-] = 10^{-6} M$



$\boxed{\text{at } 0^\circ C,\ K_w \approx 10^{-16}}$

$[H^+][OH^-] = 10^{-16}$

pH + pOH = 16

$\boxed{\text{pH of } H_2O \text{ at } 0^\circ C = 8}$